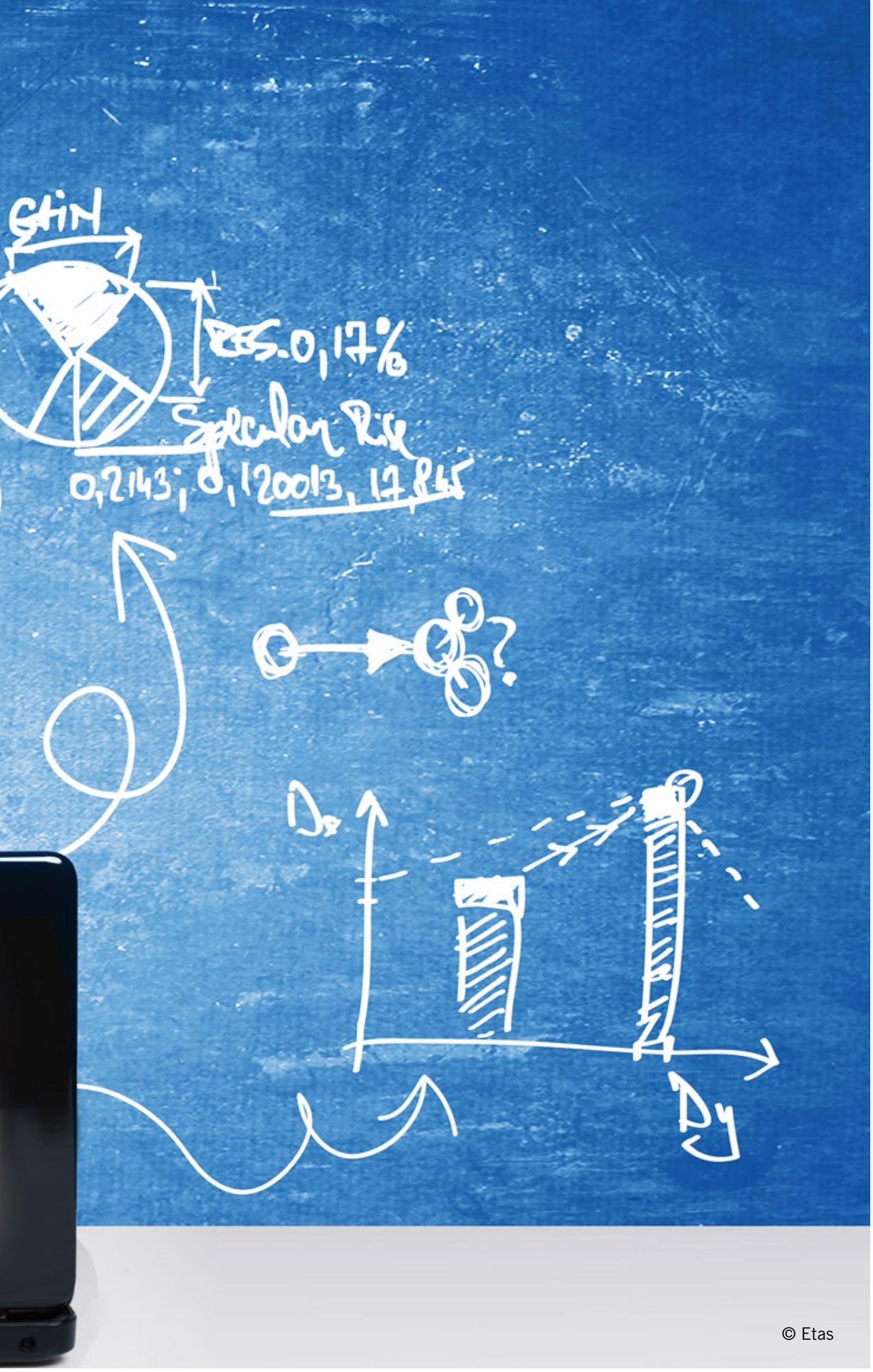
Paradigm Shift in the Market for Automotive Software

The tasks involved in automated driving cannot be mastered merely through the use of conventional control units. Powerful vehicle computers are starting to gain a foothold. This will not only revolutionize software architectures, but also the market for automotive software as a whole. A new set of standards for software architectures and vehicle computers of the future is currently emerging in the form of the Autosar Adaptive platform whose implementation phase is described here by Etas in more detail in this article.



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CAMERA AND AI REPLACE EYES AND BRAIN

When stereo cameras replace the human eye, one also needs a powerful "brain" to filter relevant information from the high-resolution 3-D image data. In the case of autonomously driving vehicles, it also needs to incorporate distance measurements from radar systems or lidar systems in the future, in addition to map and navigation data that are either saved or imported from the cloud. All of this needs to take place in real-time – and in moving traffic – at driving speeds and levels of complexity that traditional Electronic Control Units (ECUs) do not have the power to handle. In critical situations this even overwhelms the human brain: Nine out of ten traffic accidents are caused by human error.

The powerful brain of autonomously driving passenger cars will take the form of Vehicle Computers (VCs), which make around 30 trillion calculations per second. Through the use of Artificial Intelligence (AI), they analyze all incoming sensor data, usually by matching them to patterns which are already known. In terms of terabytes, they process data volumes in the upper double-digit range every hour.

VEHICLE COMPUTERS COMPLEMENT CONVENTIONAL CONTROL UNITS

Today's E/E architectures [1, 2] are not yet capable of dealing with the large quantities of data and complex, high-speed calculations required for autonomous driving. Signal transmission via conventional CAN data buses and more than one hundred ECUs – decentrally distributed throughout the entire vehicle in some cases – are not conceived for this purpose. Then there is connectivity, which will be ubiquitous in mobility scenarios in the future. Vehicles that communicate wirelessly (Over the Air, OTA) with other vehicles, infrastructures, and cloud services are capable of accommodating software updates and upgrades at a later point. This enables vehicle manufacturers to be more agile in advancing software development to include continuous delivery of new functions. However, the downside is that the risk of unauthorized or malicious access to vehicle systems increases as connectivity advances. In order to reliably defend against these risks for an entire vehicle lifetime, more

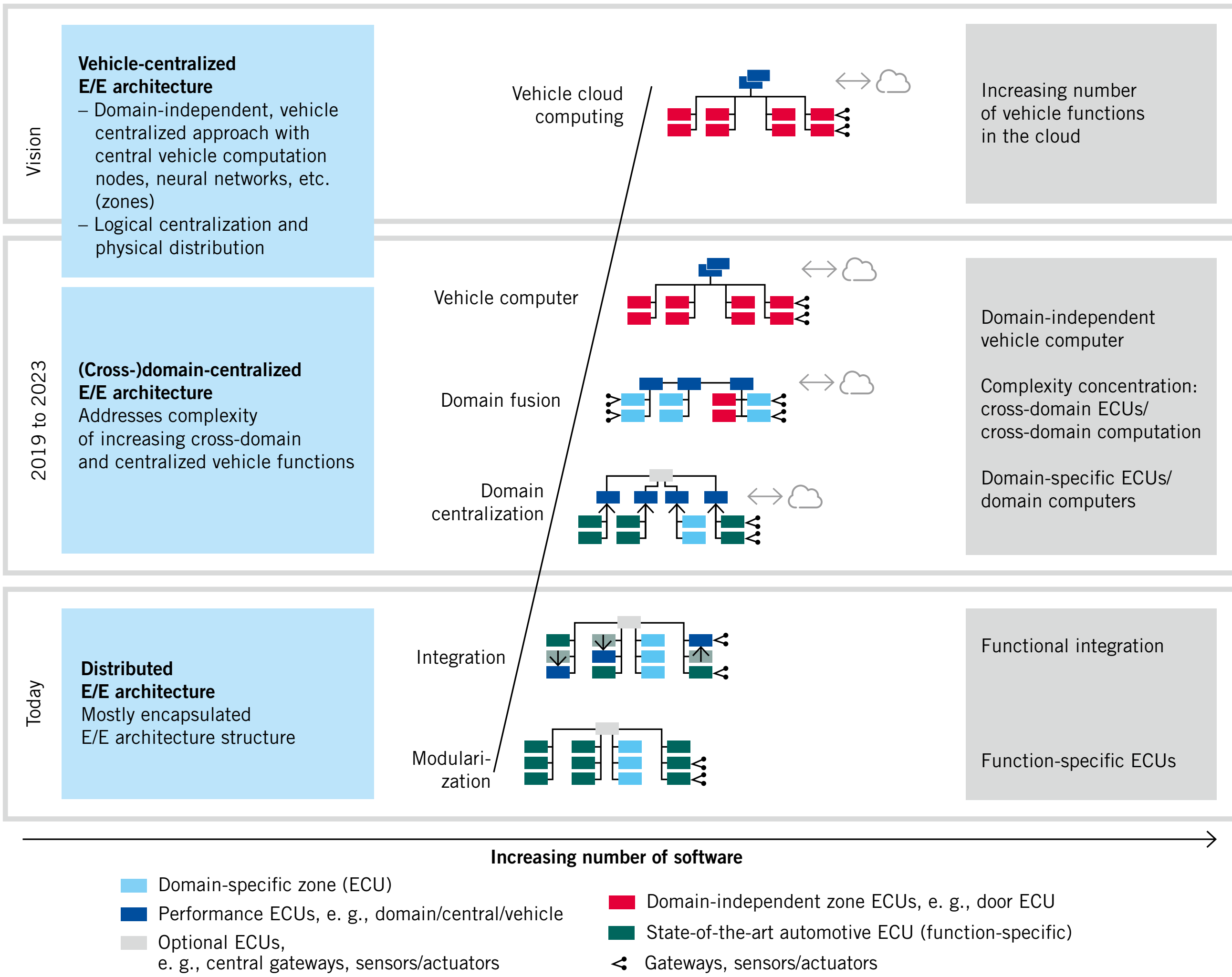


FIGURE 1 Vehicle computers and cloud connections will fundamentally change the automotive E/E architectures (© Etas)

advanced security solutions are required that can be updated at any time. In addition, there is a need to detect attacks on vehicles in the field and analyze attack patterns. Based on this, an immediate rollout of protective measures is crucial in the worst-case scenario.

Both changes – namely autonomous driving and increasing connectivity – will completely transform the vehicle electrical systems of the future, **FIGURE 1**. In terms of hardware – and as a parallel development to the classic, decentralized embedded-ECU and CAN-bus structure – a centralized network is also emerging: Within this network, the VCs will provide the required computing power, while Ethernet buses will guarantee the transmission bandwidths required for the exponentially growth of data. These new VCs will be based on powerful microprocessor technology and external memory modules, as opposed to microcontrollers with internal memory. Unlike classic ECUs, the VCs process no longer only simple, rule-based algorithms in a clearly deterministic, cyclical sequence. On the contrary: When installed in the vehicle, they bring the computing power and flexibility required to allow the vehicle to make decisions processing the data-driven algorithms of smart image processing, the fusion of sensor data, or new services related to connectivity and the cloud, on the basis of which vehicle electronics make decisions. Microcontrollers will generally only be used where there are tough, real-time demands acting on the decisions made by the VCs.

NEW START IN ARCHITECTURES WITH FAR-RANGING CONSEQUENCES

The VCs will become a key component of future E/E architectures. A more robust, centralized, and cross-domain approach will emerge in place of the domain-specific, decentralized control strategy. While today's vehicles feature a distributed system with sensors, actuators, and decentralized ECU nodes in which the driver's human brain ultimately still has the final say, future vehicles will even be able to get by without a human at the wheel. To this end, the intelligence of many ECUs will be condensed into just a few VCs. E/E architectures will become simpler and more flexible. What is more, they will be more compact, lighter and it is cheaper to develop the hardware.

Such new architectures are urgently required. After all, while classic ECU software is typically between 1 and 8 MB in size, future automotive software will grow to encompass more than 80 GB, which equates to 10,000-fold growth. Automobiles will become software-

Autosar Classic platform	Autosar Adaptive platform
Single address space (MPU support for safety)	Virtual address space for each application (MMU support)
Statically configured, signal-based communication (CAN, FlexRay)	Dynamically configured, service-oriented communication
Based on Osek	Based on Posix (PSE51)
Execution of code directly from ROM	Application is loaded from persistent memory into RAM
Statically defined task configuration	Support of mulitple (dynamic) scheduling strategies
Specification	Specification as binding standard, code as demonstrator

FIGURE 2 Main differences between Autosar Classic platform and Autosar Adaptive platform (© Etas)

dominated systems – smart devices on wheels. Today's road vehicle software already features four times as many lines of code than an airliner. Developers are now faced with the task of securely integrating 10,000 times as many lines with an ever-wider variety of software – from a tough real-time system to an innovative app. At the same time, it will be necessary to satisfy stringent safety requirements as per stage D of the Automotive Safety Integrity Level (Asil).

It is just as important to guarantee functional safety and freedom from interference as it is to have a security model that can be updated throughout the entire service life. This is where classic Autosar architectures and the entire standard reach their limits. What is needed is a new set of regulations that will not only adapt the secure integration of increasingly varied and comprehensive software, but also the centralization of the hardware. This new standard will be called Autosar Adaptive platform, **FIGURE 2** and **FIGURE 3**. The standardization committee's working groups have long been working flat-out to develop the new standard. At the same time, OEMs and their suppliers are beginning to implement and deploy the new platform. They have recognized just how radically the new architectural model will transform current business models with regard to automotive software.

NEW OPERATING SYSTEMS, APPS, AND NEW COMPETITORS

One aspect is vital for comprehending the sheer scale of the changes involved. The fact that the VCs are based on modern microprocessors and/or System-on-Chip (SoC) hardware with multiple CPU kernels, co-processors, and powerful graphics cards makes virtualized operating modes possible. To this end, the computers will be strictly partitioned to enable each partition to operate as a virtual machine. In the future, this will enable software development to be entirely separated from hardware development. Apps will be able to be installed in encapsulated partitions at all times. All software suppliers will be able to continuously optimize their products in agile development processes and update them over the air. At the same time, the market will be opened up to players from outside the automotive industry, who will be able to load software onto the partitions assigned to them. App stores and new data services may emerge while value creation in the market for automotive software will be redistributed.

As such, autonomous driving and connectivity will become the prime mover behind a radical change. Autosar Adap-

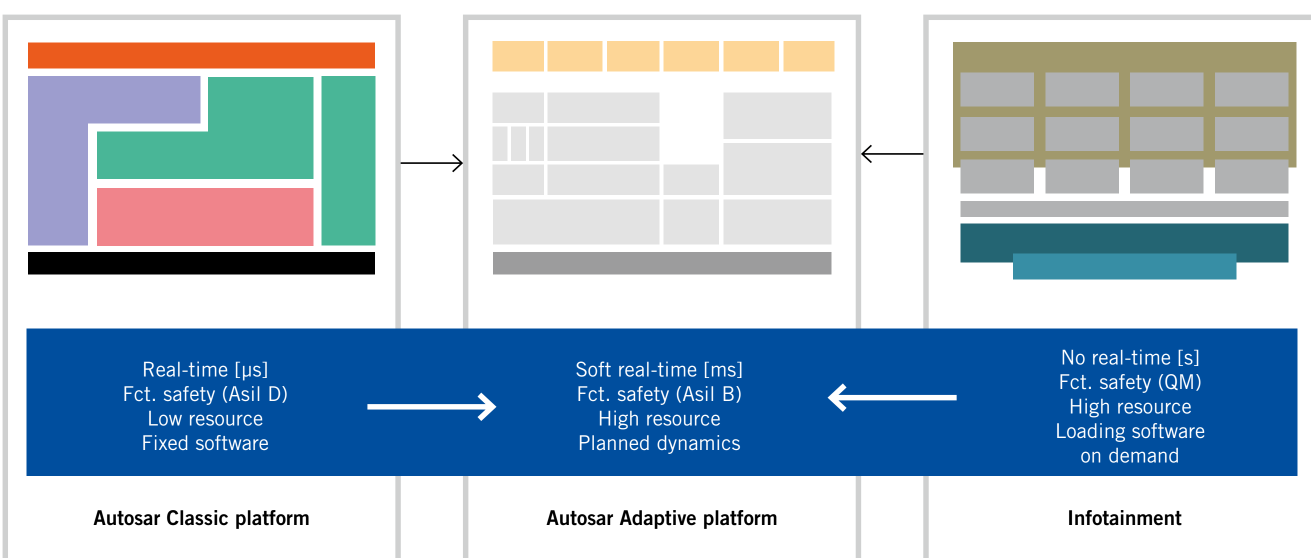


FIGURE 3 The Autosar Adaptive platform is an important link between Autosar Classic and the infotainment system of a passenger car (© Etas)

tive will provide support by setting out technical standards. Bosch and Etas recognized this aspect at an early stage and have come up with solutions that users can immediately apply to become better acquainted with the new architectures. One key element of this is the platform software framework RTA-VRTE. This acronym stands for Real-Time Application – Vehicle RunTime Environment and denotes a multi-layer platform onto which software functions can be superimposed. This framework integrates both tried-and-tested Autosar Classic sequences and new Autosar-Adaptive-compliant processes. After all, there will be parallel structures featuring classic ECUs and new VCs in the foreseeable future.

A HIGHLY VIRTUALIZED DEVELOPMENT PROCESS

An Early Access Program (EAP) enables users to get to grips with the development processes in this new environment. Those wanting to get a head-start can get their bearings quickly and to the fullest extent through consultation and training sessions, and a "ready-to-go" Software Development Kit (SDK), supported by the Etas experts with dedicated consulting and on-site training on the new architecture. In the RTA-VRTE, virtual machines assume the function of virtual ECUs, which developers can simulate on conventional desktop PCs. They are interconnected via Ethernet, which also enables them to communicate with each other.

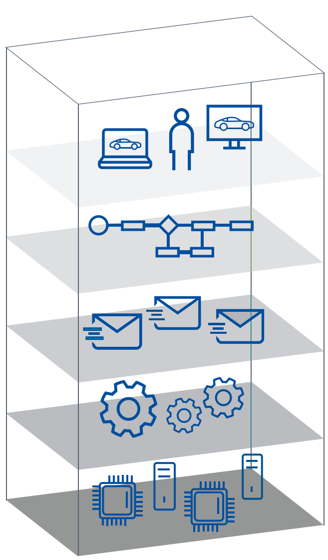
In the case of the RTA-VRTE EAP, the VC itself takes the form of a full VirtualBox model with an Autosar Adaptive architecture consisting of five levels/layers, **FIGURE 4**. Using configuration tools in the SDK, users are able to integrate a Posix-compliant Operating System (OS) of their choice. Subsystems run on the virtual machines and their respective computers, **FIGURE 5**. Interaction between them takes place in a different layer within the Autosar Adaptive platform. Dedicated communications middleware makes it impossible for unwanted interference with Asil-relevant functions to occur in the event of problems with a particular software function. This middleware also forms part of the EAP.

As such, users can immediately make a start with prototyping and penetrate the architecture, not to mention integrating, trialing, and debugging software. In addition, it is possible to integrate software solutions which are not (yet) compliant with Autosar Adaptive. These might include firewalls or gateway management systems for agile security solutions of the future, such as the Intrusion Detection and Prevention Solution (IDPS) from the Etas subsidiary Escrypt.

TWIN-TRACK ARCHITECTURE ENSURES RELIABLE VEHICLE OPERATION

In order to offer users a realistic training environment right from the outset, RTA-VRTE incorporates processes from both Autosar Classic and Autosar Adaptive. This is important: After all, many safety-relevant functions will continue to run using classic ECUs in the future because these offer advantages in cyclical, real-time processes and because their communication sequences can be monitored more easily. Alongside this, microprocessor-based VCs will deal with the more comprehensive processes of sensor-based environment recognition or of cloud-based services. These two worlds will be separated through partitioning by means of a hypervisor. A hardware abstraction layer and an additional layer for the abstraction of the selected Posix operating system in question are embedded in the solution so as to ensure the secure integration of software from various providers.

The aforementioned middleware is superimposed as a third "level" on top of these virtualized base layers and governs communication between the various on-board buses and protocols (CAN, LIN, FlexRay, Ethernet, etc.). It simultaneously converts the signals into semantic information. For example, the latter guarantees that advanced driver assistance systems can access information concerning



Application services	Functions/applications
Layer 5 Vehicle-dependent platform services	Services managing the ECU grid of the vehicle
Layer 4 ECU-dependent platform services	Services managing one specific ECU
Layer 3 Communication middleware (service-oriented)	Manages control and data flow between SW components
Layer 2 OS-dependent infrastructure SW	SW that complements the actual OS kernel (aka scheduler) and abstracts OS-specific properties toward higher layers
Layer 1 HW-dependent infrastructure SW	SW that interacts directly with HW and abstracts it toward the higher layers
Hardware	Microcontroller (µC), microprocessor (µP), Virtual Machine (VM)

FIGURE 4 The layered model of RTA-VRTE acts in support of important software functions and requirements; it consists of five levels/layers (© Etas)

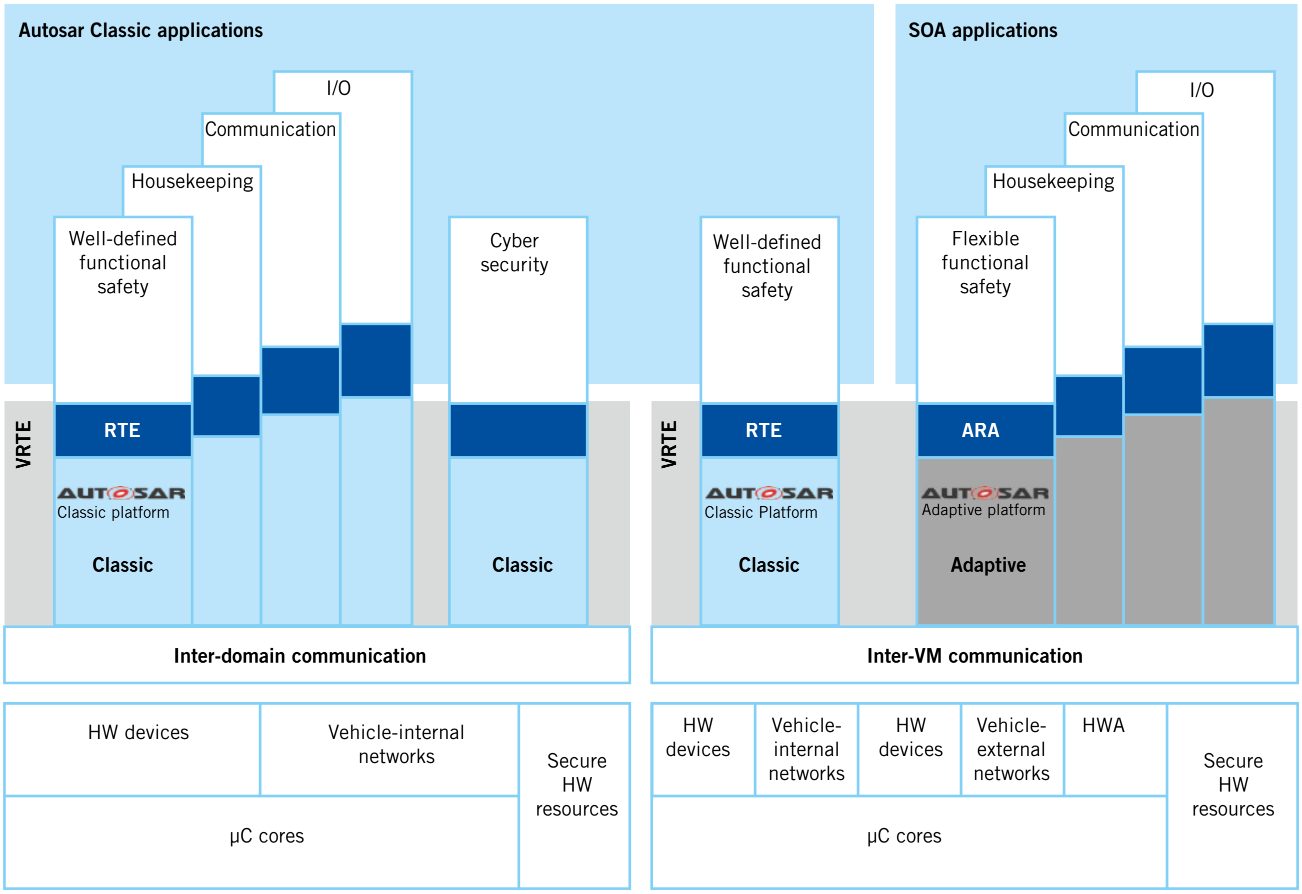


FIGURE 5 Basic structure of software for vehicle computers with Autosar Classic and Autosar Adaptive components – this structure offers maximum flexibility with a simultaneously high degree of security (SOA = Service-oriented Architecture, HW = Hardware, HWA = Hardware Abstraction) (© Etas)

the vehicle or environment at any time without delay. This flexibility in accessing information from all on-board communication buses is becoming a core challenge as the level of automation continues to increase. Additional layers firstly serve to map ECU-specific basic functions such as diagnostic or cybersecurity functions and – secondly – act as a platform for new, data-based vehicle services. These include buffers for OTA updates or security services that encompass entire vehicle fleets.

SUMMARY AND OUTLOOK

The requirements of increasingly automated driving and the connectivity of modern vehicles is pushing conventional architectures featuring decentralized, embedded ECUs and classic CAN/LIN or FlexRay data buses to their limits. As Etas shows in this article, this dilemma is solved by VCs, whose powerful microprocessor technology is not only able to deal with the massive upsurge in data volume, but also facilitates partitioning of the system into multiple virtual machines. In the future, this partitioning will completely decouple software- and hardware-development processes from one another. This will make it easier for new providers from outside the industry to gain a foothold in the market for automotive software. At the same time, this change necessitates a new framework of technical regulations. A corresponding standard is currently emerging in the form of Autosar Adaptive.

To enable OEMs and suppliers to prepare in advance for the altered market conditions and the new hybrid architectures featuring VCs and classic ECUs, Bosch, Etas, and Escrypt have issued the RTA-VRTE platform software framework and an Early Access Program that is already in use with a variety of customers worldwide. With an extensively virtualized methodology, developers today can consequently start to explore the avenues that will ultimately lead to the autonomous vehicles of the future.

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